LTE-Advanced Physical Layer Design and Test Challenges: Carrier Aggregation

Presented by
Agilent Technologies
Agenda

• Overview of carrier aggregation
  - Carrier aggregation modes
  - Operating bands
  - Cell configuration
  - Deployment scenarios
  - Layer 1 and 2 structure
  - Resource scheduling
• Design and test challenges
• Summary/Agilent solutions
• Resources
## LTE Major Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Access modes</strong></td>
<td>FDD &amp; TDD</td>
</tr>
<tr>
<td><strong>Channel BW</strong> <em>(1RB = 12 subcarriers = 180 kHz)</em></td>
<td>1.4 MHz</td>
</tr>
</tbody>
</table>
| **Transmission Scheme**      | Downlink: OFDMA *(Orthogonal Frequency Division Multiple Access)*  
Uplink: SC-FDMA *(Single Carrier Frequency Division Multiple Access)* |
| **Modulation Schemes**       | QPSK, 16QAM, 64QAM                                                                                                                                 |
| **MIMO Technology**          | Downlink: Tx diversity, Rx diversity, Single-User MIMO *(up to 4x4)*, beamforming  
Uplink: Multi-User MIMO |
| **Peak Data Rates**          | Downlink: 150 Mbps *(2x2 MIMO, 20 MHz, 64QAM)*; 300 Mbps *(4x4 MIMO, 20 MHz, 64QAM)*  
Uplink: 75 Mbps @ 20 MHz BW, 64QAM |
| **Bearer services**          | Packet only – no circuit switched voice or data services are supported ➔ voice must use VoIP |
| **Transmission Time Interval** | 1 ms                                                                                                                                 |

*March, 2014*
Release 10 and Beyond Proposals
Radio Aspects

1. Carrier aggregation

2. Enhanced uplink multiple access
   a) Clustered SC-FDMA
   b) Simultaneous Control and Data

3. Enhanced multiple antenna transmission
   a) Downlink 8 antennas, 8 streams
   b) Uplink 4 antennas, 4 streams

4. Relaying

5. Home eNB mobility enhancements

6. Heterogeneous network support

7. Self Optimizing networks (SON)

8. Coordinated Multipoint (CoMP)
What is Carrier Aggregation?

- Extends the maximum transmission bandwidth, up to 100 MHz, by aggregating up to five LTE carriers – also known as component carriers (CCs)
- Lack of sufficient contiguous spectrum forces use of carrier aggregation to meet peak data rate targets:
  - 1 Gbps in the downlink and 500 Mbps in the uplink
- Motivation:
  - Achieve wide bandwidth transmissions
  - Facilitate efficient use of fragmented spectrum
  - Efficient interference management for control channels in heterogeneous networks
Carrier Aggregation Modes

Component Carrier (CC): max 20 MHz

- **Intra-band contiguous allocation**
- **Intra-band non-contiguous allocation**
- **Inter-band allocation**

- e.g. W-CDMA carriers
### Release 10:
- Signaling to support up to 5 CCs
- Scenarios limited to 2 CCs
- Maximum aggregated bandwidth is 40MHz
- TDD inter-band with same DL-UL configurations
- Prioritized support intra band contiguous and inter band
- Rest of scenarios were postponed to later Releases

### Intra-band Contiguous CA

<table>
<thead>
<tr>
<th>E-UTRA CA Band</th>
<th>E-UTRA operating Band</th>
<th>Uplink (UL) band</th>
<th>Downlink (DL) band</th>
<th>Duplex mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>UE transmit / BS receive</td>
<td>Channel BW MHz</td>
<td>UE receive / BS transmit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$F_{UL_low}$ (MHz) – $F_{UL_high}$ (MHz)</td>
<td></td>
<td>$F_{DL_low}$ (MHz) – $F_{DL_high}$ (MHz)</td>
</tr>
<tr>
<td>CA_40</td>
<td>40</td>
<td>2300 – 2400</td>
<td>[40&lt;sup&gt;1)&lt;/sup&gt;]</td>
<td>2300 – 2400</td>
</tr>
<tr>
<td>CA_1</td>
<td>1</td>
<td>1920 – 1980</td>
<td>40</td>
<td>2110 – 2170</td>
</tr>
</tbody>
</table>

<sup>[1)</sup> For the first phase of LTE TDD CA for UE side, with eventual goal for 50MHz

### Inter-band Non-Contiguous CA

<table>
<thead>
<tr>
<th>E-UTRA CA Band</th>
<th>E-UTRA operating Band</th>
<th>Uplink (UL) band</th>
<th>Downlink (DL) band</th>
<th>Duplex mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>UE transmit / BS receive</td>
<td>Channel BW MHz</td>
<td>UE receive / BS transmit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$F_{UL_low}$ (MHz) – $F_{UL_high}$ (MHz)</td>
<td></td>
<td>$F_{DL_low}$ (MHz) – $F_{DL_high}$ (MHz)</td>
</tr>
<tr>
<td>CA_1-5</td>
<td>1</td>
<td>1920 – 1980</td>
<td>10&lt;sup&gt;1)&lt;/sup&gt;</td>
<td>2110 – 2170</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>824 – 849</td>
<td>10&lt;sup&gt;1)&lt;/sup&gt;</td>
<td>869 – 894</td>
</tr>
</tbody>
</table>

<sup>1)</sup> Only one uplink component carrier is used in any of the two frequency bands at any time.
Release 11:
- Maximum aggregated bandwidth is 40MHz
- Support multiple timing advances (required for UL CA)
- TDD inter-band with different DL-UL configurations
- Core requirements for intra-band non-cont
- Performance requirements for new inter-band and intra-band combinations

### Rel-11 inter-band Carrier Aggregation

<table>
<thead>
<tr>
<th>Carrier Aggregation</th>
<th>Rapporteur</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 7 &amp; Band 20</td>
<td>Huawei</td>
</tr>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 2 &amp; Band 17</td>
<td>AT&amp;T</td>
</tr>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 4 &amp; Band 5</td>
<td>AT&amp;T</td>
</tr>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 3 &amp; Band 20</td>
<td>Vodafone</td>
</tr>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 3 &amp; Band 5</td>
<td>SK Telecom</td>
</tr>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 1 &amp; Band 18</td>
<td>KDDI</td>
</tr>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 1 &amp; Band 19</td>
<td>NTT DOCOMO</td>
</tr>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 4 &amp; Band 13</td>
<td>Ericsson</td>
</tr>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 3 &amp; Band 5</td>
<td>SK Telecom</td>
</tr>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 4 &amp; Band 17</td>
<td>AT&amp;T</td>
</tr>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 4 &amp; Band 12</td>
<td>Cox Communications</td>
</tr>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 3 &amp; Band 8</td>
<td>KT</td>
</tr>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 3 &amp; Band 7</td>
<td>TeliaSonera</td>
</tr>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 5 &amp; Band 12</td>
<td>US Cellular</td>
</tr>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 1 &amp; Band 7</td>
<td>China Telecom</td>
</tr>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 4 &amp; Band 7</td>
<td>Rogers Wireless</td>
</tr>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 5 &amp; Band 17</td>
<td>AT&amp;T</td>
</tr>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 8 &amp; Band 20</td>
<td>Vodafone</td>
</tr>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 11 &amp; Band 18</td>
<td>KDDI</td>
</tr>
<tr>
<td>LTE Advanced Carrier Aggregation of Band 1 &amp; Band 21</td>
<td>NTT DOCOMO</td>
</tr>
</tbody>
</table>
Release 12:
- Core requirements uplink CA in inter-band
- Performance requirements for intra-band non-contiguous
- Core analysis for 3 component carriers in inter-band
- Maximum aggregated bandwidth is 50MHz

**CA Band Combinations**

Rel.10
- 3 CA Band Combinations
  1. Inter-band
  2. Intra-band cont

Rel.11
- 25 CA Band Combinations
  1. Inter-band
  2. Intra-band cont
  3. Intra non-cont

Rel.12
- 95 CA Band Combinations
  1. Inter-band
  2. Intra-band cont
  3. Intra non-cont
  4. Inter 3 CC

Rel.13
- 13 new configs so far
# New UE Categories

<table>
<thead>
<tr>
<th>UE Category</th>
<th>Data Rate DL/UL (Mbps)</th>
<th>Downlink</th>
<th>Uplink</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Max number of layers</td>
<td>Max number of layers</td>
</tr>
<tr>
<td>1</td>
<td>10 / 5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>50 / 25</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>100 / 50</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>150 / 50</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>300 / 75</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>300 / 50</td>
<td>2 or 4</td>
<td>1 or 2</td>
</tr>
<tr>
<td>7</td>
<td>300 / 100</td>
<td>2 or 4</td>
<td>1 or 2</td>
</tr>
<tr>
<td>8</td>
<td>3000 / 1500</td>
<td>8</td>
<td>4</td>
</tr>
</tbody>
</table>
Carrier Aggregation - Cell Configuration

- **PCell (primary serving cell):** handles the RRC connection establishment/re-establishment

- **SCell (secondary serving cell):** configured after connection establishment, to provide additional radio resources

- **PCell:**
  - PDCCH/PDSCH/PUSCH/PUCCH can be transmitted
  - Measurement and mobility procedure are based on PCell
  - Random access procedure is performed over PCell
  - Can not be deactivated
  - DL PCell and UL PCell are linked via SIB2

- **SCell:**
  - PDCCH/PDSCH/PUSCH can be transmitted (not PUCCH)
  - Can be deactivated by higher layer
  - Can be cross scheduled
TDD Carrier Aggregation with Different Subframe Configuration – 3GPP Release 11

- Release 10 only allowed same UL/DL configuration in all component carriers
- Release 11 different UL/DL configuration can be used – the UE is required to transmit and receive in parallel in some subframes
- TDD UEs would need duplex filter similar to FDD UEs to be able to transmit and receive simultaneously
- If UE doesn’t have duplex filter, it would follow the UL/DL configuration of PCC and conflicting subframes in SCC are not used by the UE

<table>
<thead>
<tr>
<th>PCC UL/DL Config #1</th>
<th>#0</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
<th>#6</th>
<th>#7</th>
<th>#8</th>
<th>#9</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL</td>
<td></td>
<td></td>
<td>UL</td>
<td>DL</td>
<td>DL</td>
<td>DL</td>
<td></td>
<td>UL</td>
<td>DL</td>
<td>DL</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SCC UL/DL Config #2</th>
<th>#0</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
<th>#6</th>
<th>#7</th>
<th>#8</th>
<th>#9</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL</td>
<td></td>
<td></td>
<td>UL</td>
<td>UL</td>
<td>DL</td>
<td>DL</td>
<td></td>
<td>UL</td>
<td>UL</td>
<td>DL</td>
</tr>
</tbody>
</table>

Subframes 3 and 8 of SCC can only be used by full-duplex UEs
Carrier Aggregation Deployment Scenarios (1 of 2)

Scenario #1:
• F1 and F2 cells are co-located and overlaid, providing same coverage.
• Likely scenario when F1 and F2 are of the same band.

Scenario #2:
• F1 and F2 cells are co-located and overlaid, but F2 has smaller coverage
• Only F1 provides sufficient coverage and F2 is used to improve throughput.
• Likely scenario when F1 and F2 are of different bands

Scenario #3:
• F1 and F2 cells are co-located but F2 antennas are directed to the cell boundaries of F1 so that cell edge throughput is increased.
• F1 provides sufficient coverage but F2 potentially has holes
• Likely scenario when F1 and F2 are of different bands
**Scenario #4:**
- F1 provides macro coverage and on F2 Remote Radio Heads (RRHs) are used to improve throughput at hot spots.
- Likely scenario when F1 and F2 are of different bands,

**Scenario #5:**
- Similar to scenario #2, but frequency selective repeaters are deployed to extend coverage for one of the frequencies.
Layer 2 Structure for Carrier Aggregation

- Data aggregation happens in MAC layer, changes to protocol layer is kept to a minimum except some new RRC messages to add, remove or reconfigure SCC
- The MAC layer divides the data between different CCs and separate HARQ processes for each CC
MAC to Physical Layer Mapping for Carrier Aggregation

- There is one transport block, up to two in case of spatial multiplexing, and one HARQ entity per scheduled component carrier.
- A UE can be scheduled over multiple component carriers simultaneously.

Example of 5 component carriers each with different modulation format.
Resources can be assigned to a user equipment (UE) in two ways:

- Same-carrier scheduling
- Cross-carrier scheduling
Same Carrier Scheduling

- Separate PDCCH for each CC
- Resource scheduling are on the same component carrier (Downlink assignments/ Uplink grants)
- Reusing Release 8/9 PDCCH structure and DCI (Downlink Control Information) formats for backward compatibility
- Each component carrier can be analyzed individually

PDCCH (Physical Downlink Control Channel) carries the uplink and downlink resource grant.
Cross Carrier Scheduling

- Common PDCCH (on PCell) for multiple CC
- Resource scheduling are NOT on the same component carrier (downlink assignments/ uplink grants)
- New carrier indicator field (CIF) in DCI
- Analysis of one carrier depends on another carrier

![Diagram of LTE Advanced Carrier Aggregation](image)
Cross-Carrier Scheduling: 
Interference management for control channels in heterogeneous networks

- Cross-carrier scheduling provides interference management for control channels known as Inter-Cell Interference Coordination (ICIC) for PDCCH.
- In this example, CC1 of Macro Cell would cause high interference to CC1 of pico cell, therefore pico cell uses CC2 for PDCCH messages to schedule PDSCH transmission on CC1.
- Macro cell uses CC1 to schedule PDSCH transmission on both CC1 and CC2.

Cross-carrier scheduling avoids control channel interference.
An Example Configuration of Cross Carrier Scheduling

CC#1
10 MHz
ServCellIndex: 0 (Pcell)

CC#2
10 MHz
ServCellIndex: 1 (Scell)

Same Carrier scheduled PDSCH:
- “PDSCH start” symbol is obtained by decoding PCFICH (PCFICH carries how many PDCCH symbols are transmitted)
- PDSCH allocation is defined in PDCCH(DCI) in CC#1

Cross carrier scheduled PDSCH:
- “PDSCH start” symbol is given by a higher layer parameter
- PDSCH allocation is defined in PDCCH(DCI) in CC#1
Enhancement of Uplink Control Information (UCI) for Carrier Aggregation

Updated UCI to support up to 5 downlink CCs

**New PUCCH format 3**
- Convey large ACK/NACK payload (48 coded bits)
- QPSK modulation
- Not based on Zadoff-Chu sequences, uses **DFT-S-OFDM** similar to PUSCH transmissions

**Enhanced PUCCH format 1b with channel selection**
- Supports up to 4 ACK/NACK bits for 2 CCs

**Update control data bits on PUSCH**
- The number of HARQ-ACK, RI and CQI/PMI bits are **increased**
Agenda

• Overview of carrier aggregation
  - Carrier aggregation modes
  - Operating bands
  - Cell configuration
  - Deployment scenarios
  - Layer 1 and 2 structure
  - Resource scheduling

• Design and test challenges

• Agilent solutions

• Resources
UE Transmitter Architecture for Various Intra-Band Aggregation Scenarios

**Scenario A**

- Multiplexer 1 and 2 BB
- IFFT
- D/A
- RF PA
- RF filter

Single (baseband + IFFT + DAC + mixer + PA)
Aggregation Scenario: Intra-band contiguous

**Scenario B**

- Multiplexer 1 BB
- IFFT
- D/A
- RF PA
- RF filter

- Multiplexer 2 BB
- IFFT
- D/A
- RF PA

Multiple (baseband + IFFT + DAC), single (stage-1 IF mixer + combiner @ IF + stage-2 RF mixer + PA)
Aggregation Scenarios: Intra-band contiguous and non-contiguous

**Scenario C**

- Multiplexer 1 BB
- IFFT
- D/A
- RF PA
- RF filter

- Multiplexer 2 BB
- IFFT
- D/A
- RF PA

Multiple (baseband + IFFT + DAC + mixer), low-power combiner @ RF, and single PA
Aggregation Scenarios: Intra-band contiguous and non-contiguous

Reference: 3GPP TR 36.912 v.10.0.0. Figure 11.3.2.1-1
### UE Receiver Architecture

#### Rx Characteristics

<table>
<thead>
<tr>
<th>Option</th>
<th>Description (Rx architecture)</th>
<th>Intra Band aggregation</th>
<th>Inter Band aggregation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Contiguous (CC)</td>
<td>Non contiguous (CC)</td>
</tr>
<tr>
<td>A</td>
<td>Single (RF + FFT + baseband) with BW&gt;20MHz</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Multiple (RF + FFT + baseband) with BW≤20MHz</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Option A**

Single wideband-capable (i.e., >20MHz) RF front end (i.e., mixer, AGC, ADC) and a single FFT, or alternatively multiple "legacy" RF front ends (<=20MHz) and FFT engines.

**Option B**

In the case non adjacent Inter band separate RF front end are necessary.

Reference: 3GPP TR 36.912.
Design Challenges – Intra-Band CA

- Several technical challenges, especially for a UE
- From RF perspective, intra-band contiguous aggregated carriers have similar properties as a corresponding wider carrier being transmitted and received
- Release 10 requires more stringent linearity requirements on the power amplifier than Release 8/9
  - UE will need to use less transmitter power for the amplifier to remain in the linear region
- Use of multiple CC on UL should be optional and only used for cases where UEs are not at the cell edge
- For the base station, it has less impact - similar to multi-carrier configuration already supported in earlier releases

Example of CCDF plot using N7624B LTE/LTE-Advanced Signal Studio software
Design Challenges - Inter-band CA

Major challenges for the UE

• Multiple simultaneous receive chains
• Multiple simultaneous transmit chains

Challenging radio environment

• In terms of intermodulation and cross-modulation within the UE device.
• Need to design front-end components that help reduce harmonics, and other intermodulation products, which meet 3GPP requirements.
• Simultaneous transmit or receive with MIMO support add significantly to the challenge of antenna design

Less impact for the base station

• Similar to current base stations supporting multi-bands

Reference:
3GPP TR 36.912 v.10.0.0. Figure 11.3.2.1-1
## SystemVue LTE-Advanced Carrier Aggregation

<table>
<thead>
<tr>
<th>Scenario number</th>
<th>Deployment scenario</th>
<th>Transmission BWs of LTE-A carriers</th>
<th># of LTE-A component carriers</th>
<th>Duplex modes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Single-band contiguous spec. alloc. @ 3.5GHz band for FDD</td>
<td>UL: 40 MHz DR: 80 MHz</td>
<td>UL: Contiguous 2x20 MHz CCs DR: Contiguous 4x20 MHz CCs</td>
<td>FDD</td>
</tr>
<tr>
<td>2</td>
<td>Single-band contiguous spec. alloc. @ Band 40 for TDD</td>
<td>100 MHz</td>
<td>Contiguous 5x20 MHz CCs</td>
<td>TDD</td>
</tr>
<tr>
<td>4</td>
<td>Single-band, non-contiguous spec. alloc. @ 3.5GHz band for FDD</td>
<td>UL: 40 MHz DR: 80 MHz</td>
<td>UL: Non-contiguous 1x20 + 1x20 MHz CCs DR: Non-contiguous 2x20 + 2x20 MHz CCs</td>
<td>FDD</td>
</tr>
</tbody>
</table>

![Diagram](image-url)
Test Challenges: Power Amplifier Characterization

**Test Challenge:** Characterizing the LTE-Advanced UE or eNB power amplifier presents RF challenge. The different carrier aggregation configurations will stress the amplifier in different ways since each will have different peak-to-average ratios.

Agilent Solution:
- Signal Studio software generates LTE-Advanced signals compliant to 3GPP standard to test power and modulation characteristics of components and transmitters.
- Supports up to 5 component carriers within up to 160 MHz I/Q bandwidth with MXG vector signal generator
- CCDF curve to get insight into the waveform power statistics as system parameters are varied
Test Challenges: Analyze eNB Unwanted Emissions inside Sub-Block Gap

Test Challenge: For Release 11, there is new RF conformance testing required for base station transmitters to measure unwanted emissions inside sub-block gap contributed from carriers on both sides of the gap.

Agilent Solutions:
- X-Series LTE-Advanced measurement application (N9080B/N9082B)
- Supports LTE-Advanced RF conformance testing per 3GPP Release 10/11 for both UE and eNB
- Supports the new cumulative ACLR (CACLR) and cumulative SEM requirement inside sub-block gap

Depending on sub-block gap, one or both inner offsets can overlap resulting in CACLR.

Refer to “LTE-Advanced Base Station RF Conformance Testing” paper for full detail on RF conformance testing.
Test Challenges: Inter-Band Carrier Aggregation Analysis

**Test Challenge:** acquiring truly simultaneous events across carriers is important in device verification and troubleshooting tasks but in inter-band case, this would require signal analyzer with bandwidth that spans multiple frequency bands (ex. 800 MHz and 2100 MHz)

**Agilent Solution:**
- Dual input hardware, fully synchronized, plus 89600 VSA software. VSA software acquires all the CCs simultaneously, demodulate the captured signals, and analyze them all simultaneously.

*Images of dual signal analyzers and VSA software screenshots displaying 2 CCs at 800 MHz and 3 CCs at 2100 MHz.*
Test Challenges: Analyze Time Alignment Error between Multiple Component Carriers

**Test Challenge:** In order for the UE to properly receive the multiple component carriers from the eNB, the timing offset between the component carriers must be kept at a minimum - 155 ns for intra-band contiguous; 285 ns for non-contiguous & inter-band

**Agilent Solutions:**

89600 VSA software

- Both simultaneous and sequential demodulation of component carriers to perform time alignment error (TAE) measurement

**X-Series Measurement Application**

- Sequential acquisition of the multiple component carriers. Use frame trigger or external trigger for accurate TAE measurement

89600 VSA Cross-carrier Summary trace providing TAE across all CCs
Test Challenges: Simultaneous Analysis of Inter-Band Aggregation plus Downlink MIMO

Test Challenge: when inter-band carrier aggregation is combined with spatial multiplexing MIMO, it requires test tools that has a minimum of 4 inputs (two inputs per CC).

Agilent Solution:
• N7109A multi-channel signal analysis system: 2, 4 or 8 channels, 40 MHz demodulation BW per channel

Example of 2x2 MIMO and inter-band carrier aggregation with two component carriers
Test Challenges: LTE-Advanced eNB Receiver Test

**Test Challenge:** Test eNB ability to decode UCI transmissions with feedback for multiple component carriers.

**Agilent Solution**

- Create either FDD or TDD signals
- PUCCH format 3 and 1b enable generation of feedback for multiple component carriers
- PUSCH UCI multiplexing enhanced for feedback of up to 5 component carriers
- Predefined configuration of LTE-Advanced conformance tests with randomized HARQ-ACK in PUCCH
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- Design and test challenges
- Summary/Agilent solutions
- Resources
Summary

• Carrier aggregation is one of the most important features for LTE-Advanced enabling:
  - Higher data rates
  - Facilitate efficient use of fragmented spectrum
  - Interference management in heterogeneous networks
• It is introduced in LTE Release 10 with enhancements in Release 11 and more improvements planned in Rel. 12 and beyond
• It introduces various design challenges, especially for UE
• New test challenges for both UE and eNB
• Agilent was first to market with LTE-Advanced solution addressing system simulation, signal generation and analysis tools
Agilent LTE and LTE-Advanced Portfolio

First LTE-A

SystemVue (BB) ADS/GG (RF/A)
Signal creation software

Signal Generators
Baseband Generator and Channel Emulator

RF Module Development
RF Proto → RF Chip/module

BTS and Mobile BB Chipset Development
L1/PHY
FPGA and ASIC

Protocol Development
L2/L3

RF and BB Design Integration
L1/PHY
DigRF v4

BTS or Mobile

System Design Validation
System Level RF Testing

Pre-Conformance

Conformance

Manufacturing

Network Deployment

Anticipate Accelerate Achieve

Agilent Technologies

March, 2014
LTE/LTE-Advanced Signal Studio Software
For RF Transmitter & Receiver Tests

Physical layer-coded signals for Transmitter amplifier test (Basic option)
Transport layer-coded signals for Receiver BLER test (Advanced option)

- User-friendly, parameterized, and reconfigurable setup
- Real-time uplink LTE FDD / TDD signal creation
- Create multi-carrier signals in one waveform
- Create MIMO precoding with embedded multi-path fading
- Supports multiple signal-generator platforms:

- X-Series MXG/EXG
- PXB
- EXM
- 1st generation MXG
- ESG-C / PSG
- M9381A VSG
- SystemVue EDA software
Signal Studio LTE and LTE-Advanced
Version 12.0 (Released March 2014)

- **Uplink MIMO** (Advanced R10, Option TFP/TTP)
  - 2x and 4x ANT
  - Spatial Multiplexing for PUSCH
  - OCC for PUSCH DMRS
  - SORTD for PUCCH
  - PUCCH wizard to support uplink MIMO tests (8.3.7, 8.3.8)

- **Other LTE-A uplink features**
  - Carrier Aggregation
  - PUCCH format 3, 1b with channel selection
  - Clustered PUSCH
  - Simultaneous PUSCH/PUCCH

- **Downlink**
  - Downlink Control Information (DCI) updates
    - DCI format 4 is added
    - Other DCI formats also updated
  - Carrier Aggregation
N7649B Test Case Manager
Now Supports Receiver Performance Tests

• Simple and easy to use user interface
  - Provides minimum set of parameters and configure instruments according to the standard requirements
• TS36.141 Receiver Test for FDD and TDD
  - Clause 7 Receiver Characteristics (Rel-10)
  - Clause 8 Receiver Performance (Rel-9)
  - eNB Type selection
    • Wide Area, Local Area, Home BS
• Supported Platforms
  - Clause 7: MXG-B, EXG-B, MXG-A, ESG-C, PXB
  - Clause 8: MXG-B(*), EXG-B(*), PXB
    • * Requires external fader
• Graphic to show how carriers are positioned
• SCPI log to assist remote automation
• 30 days free trial license is available

Visit [www.agilent.com/find/TCM](http://www.agilent.com/find/TCM) to find out more!
**LTE/LTE-Advanced Signal Analysis Applications**

**For RF Transmitter Test**

**Scalable transmitter test solutions**

- Tailor capability & performance from SISO to MIMO/beamforming

- Use 89600 VSA with varieties of demodulation result traces/capabilities for deep-dive analysis in R&D, design validation, troubleshooting, etc.

- Use X-Series measurement applications with ease-of-use presets, demodulation and power/ spectrum measurements for manual & automated tests in QA, conformance testing, manufacturing, etc.

**Co-reside with multi-formats in one box**

- W-CDMA/HSPA+, GSM/EDGE, cdma2000, 1xEV-DO, WLAN…

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**X-Series Signal Analyzer**

(EXA/MXA/PXA)

89600B VSA Software

Ultimate analysis flexibility for R&D

N9080B/82B Software

One-button measurements for conformance testing

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Carrier Aggregation: Simultaneous demodulation of up to 5 CCs.

- DL (OFDMA) & UL (SC-FDMA) in a single option
- All LTE/LTE-A modulation types: BPSK, QPSK, 16QAM, 64QAM, CAZAC (Zadoff-Chu)
- FDD/TDD 4x4 DL MIMO analysis & TDD 8x2 DL Beamforming analysis
- 8x8 DL MIMO analysis for LTE-Advanced FDD & TDD
- UL MIMO single channel analysis for LTE-Advanced
- 89600 WLA: MAC, RRC, RLC layer add-on to the 89600 VSA for UL & DL LTE FDD
- Rich varieties of modulation analysis results & traces with full PHY channel-based color coding
- Supports multiple platforms: Systemvue EDA simulation SW, X-Series signal analyzers, Oscilloscopes, logic analyzers, PXI VSAs, N7109A multi-channel signal analyzer
Output power level tests
- Channel power
- Transmit ON/OFF power (TDD base station only)

Transmitted signal quality
- EVM, frequency error, I/Q offset...
- Time alignment error
- Comprehensive list of EVM measurements and color-coded displays to troubleshoot errors

Unwanted emissions
- Spectrum emissions mask (SEM)
- Adjacent channel leakage ratio (ACLR)
- Cumulative ACLR (CACLR) and cumulative SEM for non-contiguous CA
- Occupied bandwidth
- Spurious emissions
- Transmitter intermodulation

All measurements support LTE and LTE-A with up to 5 component carriers, both contiguous and non-contiguous carrier aggregation (CA)
Chapters in this 600 plus page book include:
- LTE Introduction
- Air Interface Concepts
- Physical Layer
- Upper Layer Signaling
- System Architecture Evolution
- Design and Verification Challenges
- Conformance Test and Acceptance Testing
- Looking Towards 4G: LTE-Advanced

Agilent LTE-Advanced solution information:
www.agilent.com/find/lteadvanced

3GPP specification:
http://www.3gpp.org/DynaReport/36-series.htm
Thank you for listening!